

1.3 Blood



Your school is organizing a blood drive for the local blood bank. If you have not given blood before, you probably have questions about what will happen during the donation. Before blood is donated, potential donors—aged 17 or more—are asked a list of questions about their general health, their travel history, and their participation in certain activities. The answers determine if there is a risk that the donor’s blood carries a disease that could be passed on to the person receiving the blood. In addition to medical concerns, some people are prohibited from donating blood or receiving transfusions for religious reasons.

If you are able to participate, a nurse will test your temperature and blood pressure to see if you are healthy enough to donate. The nurse will also take a drop of blood from your finger and time how long it takes for the blood to sink in a solution to examine the oxygen-carrying capacity of your red blood cells.

The nurse will then insert a sterile needle into a vein in your arm and take about 450 mL of blood. Your body contains about 5 L of blood, and this small donated volume of 450 mL will quickly be replaced by new blood cells formed in the spongy marrow inside your bones. Since the donated blood can become thick and clot quickly in the air, a chemical called an anticoagulant must be added to stop the collected sample from clumping.

The collected blood will then be taken to a lab where it will be tested to ensure it is free of dangerous diseases, such as hepatitis and HIV. Once this screening process is complete, the donated blood may be given to patients who have a need for the entire sample or some of its components.

It may be donated as whole blood, but later the individual parts of blood may be separated. Some patients require the portion that causes clotting, while others are given only the liquid part of blood to replace fluids they have lost in an accident or during major surgery. It is estimated that one blood donation is able to help three other people, and it quite often helps save lives.

Blood is the fluid of life. Because the jobs performed by blood are so important, people die if they lose too much of this vital fluid. Since the average adult only has about 5 L of blood, it must be quickly cycled by the circulatory system to efficiently carry out its jobs. In previous lessons you learned that blood is constantly circulated throughout the body so it can deliver oxygen and nutrients and remove wastes from cells as they carry out their functions—however, blood also transports other materials such as chemical messengers (called hormones), vitamins, and minerals. Blood also helps to protect people’s bodies from disease and maintains water balance, temperature, and pH. Health-care workers examine blood samples from people who are not feeling well because irregularities in a blood sample can help diagnose an imbalance in the body.

Try This Activity

A Circle Diagram for Blood

So many images come to mind when we think about blood because we are aware of the vital importance of this fluid flowing within our bodies. Just the sight of lost blood makes some people uncomfortable. Blood is often used as a symbol of our spirit and can signify both life and death. Children are someone's "flesh and blood," murderers have "blood on their hands," something that you were meant to do is "in your blood," and hard work requires "blood, sweat, and tears."

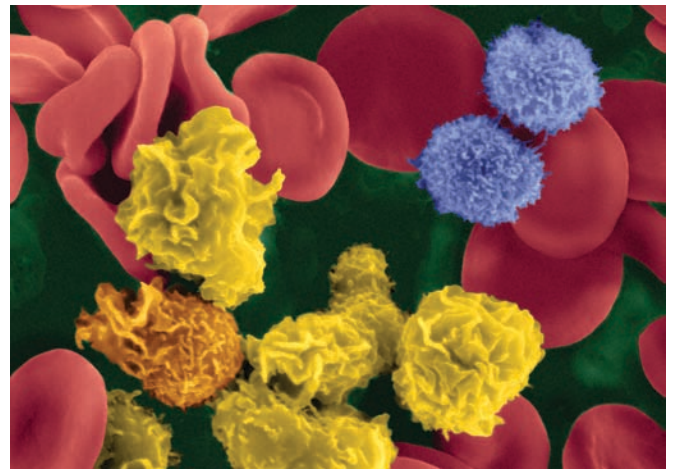
Place the word *blood* within a small circle at the centre of a blank page. Draw a larger circle around the smaller one. Brainstorm all the different ideas, terms, metaphors, symbols, and sayings that come to mind with this word and write them within the larger circle. Draw a box around the large circle. Determine the sources for ideas and terms that you wrote within the larger circle, and write these terms within the box. As an alternative, this activity may be done in small groups or as a class, with many students contributing to the formation of one circle diagram.

Blood Components

Blood appears to be a liquid with a uniform red colour, but blood is actually a mixture of living cells and pieces of cells suspended in a broth-like liquid. If you let a blood sample sit for a while or spin a blood sample in a machine called a centrifuge, the blood separates into layers to reveal its different parts.

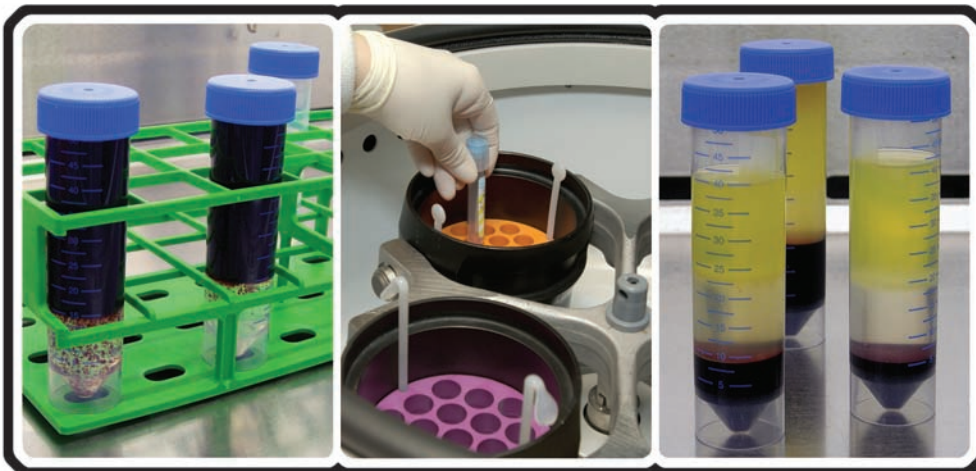
At the bottom of the centrifuge sample, the red blood cells are clearly visible. The pale yellow liquid that is seen to occupy the top half of the blood samples is called **plasma**.

Plasma is like the broth of a soup because it is mostly water with substances dissolved or floating in it. About 55% of blood volume is due to the watery plasma. In between the plasma and the red blood cells is a section of clear fluid containing the **white blood cells** and **platelets**. Platelets contribute the smallest amount to the volume of blood.



White blood cells are designed to protect the body from disease-causing organisms and other harmful materials. Sometimes these foreign substances enter the body through a cut in the skin. At the site of a cut, the platelets are tiny fragments of cells that play a key role in helping blood clot. The clot eventually hardens to form a scab that keeps the wound clean while new replacement skin grows. In this lesson you'll learn more about the roles played by plasma, red blood cells, white blood cells, and platelets.

Separation of Blood into Components



- ▶ **plasma:** the pale yellow fluid portion of blood where the cells are suspended
- ▶ **white blood cell:** a colourless blood cell that acts to defend the body against diseases and other foreign invaders
- ▶ **platelet:** a particle found in the bloodstream that begins the blood-clotting process at the site of a wound

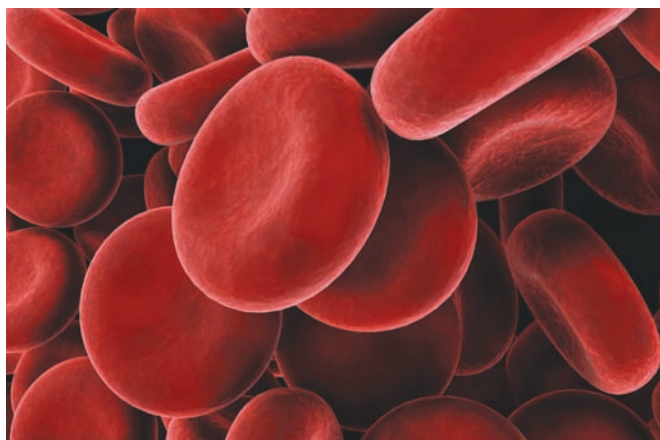
Practice

Obtain a copy of the handout “Separating Blood into Its Components” from the Science 30 Textbook CD. Use this handout to answer questions 23 and 24.



23. Add the following labels to this diagram: red blood cells; plasma; white blood cells; platelets; sample of blood prior to placement in centrifuge; sample of blood after removal from centrifuge; and centrifuge.
24. Identify the blood component(s) that best describes each of the following statements.
 - a. This component comprises about 55% of blood volume.
 - b. This component makes up almost 45% of the total volume of blood.
 - c. Together, these components comprise less than 1% of the total volume of blood.

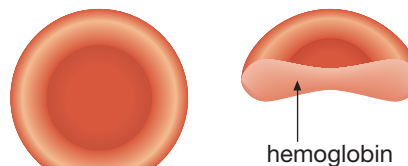
Red Blood Cells



Red blood cells, also called **erythrocytes**, are the most numerous cell type in a blood sample. In one drop of blood there are about one million red blood cells. These cells are designed to transport oxygen. They are shaped like a covered inner tube, with a depression in the middle but not a hole. This distinctive shape—called **biconcave**—allows them to slide through the blood vessels with ease. If their shape were more square or jagged they might stick to each other or the vessel walls, which would result in a jam that slows or stops circulation in that vessel. The cream-filled, doughnut-like shape provides a large surface area to volume ratio for an efficient gas exchange.

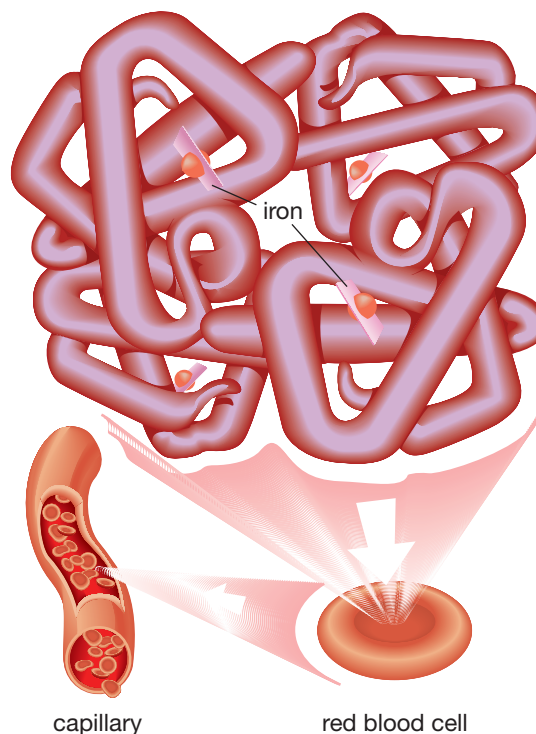
- ▶ **erythrocyte**: a term for a red blood cell that contains hemoglobin and transports oxygen from the lungs to the body's cells
- ▶ **biconcave**: the distinctive shape of red blood cells where the cells are flat but dip inwards at the centre on both the top and bottom
- ▶ **hemoglobin**: an iron-containing pigment that binds oxygen to facilitate its movement in the circulatory system
- ▶ **oxyhemoglobin**: a hemoglobin bound with oxygen that appears bright red in colour

red blood cell red blood cell cut in half



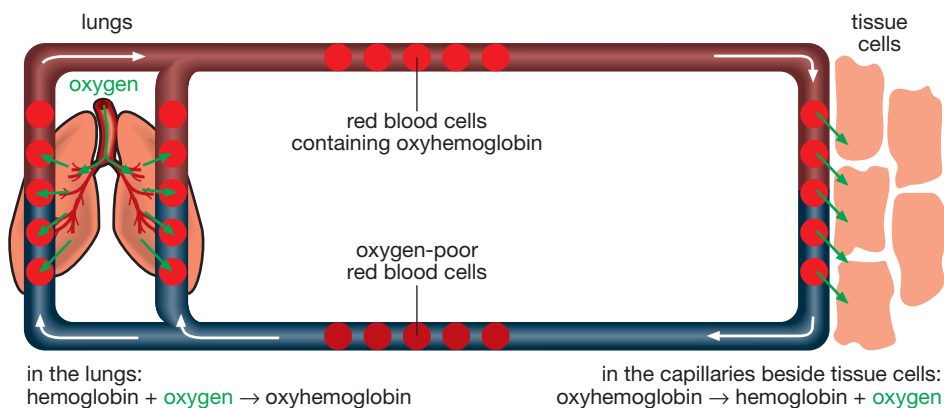
A red blood cell's lifespan in the bloodstream is about 120 days. As red blood cells die, they are absorbed by the liver and are soon replaced with new cells produced in the bone marrow. The bone marrow produces millions of red blood cells every second. Each red blood cell takes about two days to develop. As the red blood cells mature and are released from the bone marrow, they lose their nucleus. Having no nucleus provides extra room to pack the cell full of the **hemoglobin** molecule.

Hemoglobin Molecule



Hemoglobin is a pigment that gives the red blood cells and whole blood their red colour. It contains iron which interacts with the oxygen present in the lungs. A hemoglobin called **oxyhemoglobin** is bound to oxygen and has a bright red colour.

As red blood cells pass through the lungs, hemoglobin molecules pick up oxygen molecules to form oxyhemoglobin. The red blood cells are transported through arteries, arterioles, and eventually to capillary beds next to body tissues. As these cells slowly pass through capillaries near tissue cells, the reaction is reversed: the oxygen is released and the blood loses its bright red colour.



Investigation

Iron-Fortified Cereals

Background Information

New red blood cells are constantly being made to replace old red blood cells, and iron is needed for the production of the red blood cell's hemoglobin. Good sources of iron include foods such as meat, fish, poultry, beans, dried fruits, and whole grain breads. For people who don't receive enough iron through their regular diet, it is beneficial for them to supplement their iron supply by eating foods with added iron. Many cereal companies advertise that their product is "fortified with iron."

Purpose

You will separate the iron from breakfast cereal enriched with iron.

Materials

- 750 mL (3 cups) of iron-fortified cold breakfast cereal
- mortar and pestle or a rolling pin
- two 1000-mL beakers
- magnetic stirrer complete with magnetic stir bar and magnetic retrieval wand
- 700 mL of distilled water
- plastic rinse bottle with distilled water

Procedure

- step 1:** Crush the cereal with a rolling pin or a mortar and pestle until the cereal becomes a fine powder. Place the powdered cereal in one of the 1000-mL beakers.
- step 2:** Add 700 mL of distilled water to the other 1000-mL beaker.
- step 3:** Carefully add the stir bar to the beaker's bottom and place the beaker on the magnetic stirrer. If the magnetic stirrer is combined with a hot plate, do not turn on the hot plate.



Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

step 4: Turn on the magnetic stirrer at a moderate speed setting. While it is spinning, carefully add the powdered cereal. The rotation speed may have to be increased.

step 5: Stir for approximately 30 minutes.

step 6: Turn off the magnetic stirrer. Use the retrieval wand to carefully remove the stir bar. Gently rinse any cereal off the stir bar and then observe its surface.

Analysis

1. State the iron property that accounts for what you observed on the magnetic stir bar's surface.
2. People who don't get enough iron from their diets, or those people who suffer from chronic blood loss, have lowered red blood cell levels and can develop a blood condition called *anemia*. Based on your knowledge of red blood cell functions, what symptoms do you think people with anemia might have?
3. One test used to see if potential blood donors have anemia is to put a drop of a donor's blood in a vial of thick blue fluid. If the blood drop falls very slowly or does not sink at all, it could be a sign that the donor is anemic or low in red blood cells on that particular day. Explain why a sample of blood from someone who has anemia might fall less quickly than a sample of blood from a person who does not have anemia.
4. To stay healthy, men require about 10 mg of iron per day and women about 15 mg per day. Pregnant women daily need about 30 mg of iron. Explain why pregnant women might require double the mass of iron required by women who are not pregnant.

Science Links

The interaction of iron objects with a magnet played a key role in “Iron-Fortified Cereals.” In Unit C you will continue to explore these effects by studying the interaction between magnetic effects and electrical effects.

White Blood Cells

White blood cells, also called **leukocytes**, are much larger than red blood cells and are found in much lower numbers. In a healthy individual there is only about one white blood cell for every 600 to 700 red blood cells. Like red blood cells, leukocytes are made in a person’s bone marrow. Unlike red blood cells, leukocytes keep their nucleus when they mature. Their shape is not uniform and they lack a colour pigment. In prepared slides and photographs, white blood cells are often stained so that they can be observed more clearly. The life span of a white blood cell is generally about 13 to 20 days.

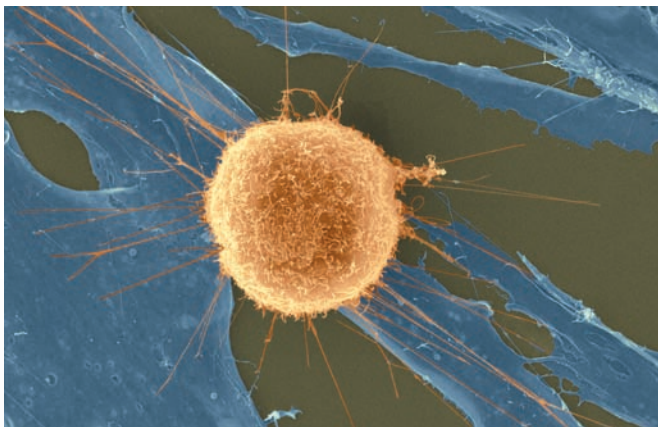


Figure A1.10: A human white blood cell attacks cancer cells.

When disease-causing organisms enter the body, the number of white blood cells increases by releasing stored white blood cells from the body or producing more in the bone marrow. A doctor will often request that a white blood cell count be performed in a blood sample. Elevated white blood cell counts usually signal an infection.

- ▶ **leukocytes:** a term for white blood cells
- ▶ **protein:** a large organic molecule consisting of a chain of amino acids; an essential building block of all cells that plays a key role in the functioning of body systems
- ▶ **fibrinogen:** a soluble protein present in blood plasma that converts to fibrin when blood clots

Practice

25. Cancer patients often experience extreme fatigue because the cells in their muscle tissues are oxygen depleted. This condition exists because the chemotherapy many patients undergo to treat their cancer has a side effect of reducing the number of blood cells.
- a. In these circumstances, identify what type of blood cells are especially needed by cancer patients.
 - b. The type of blood cells in question 25.a. must be separated from whole blood. Describe a process that could separate whole blood into its components.
26. The body produces millions of red blood cells in the bone marrow every second. White blood cells are made in bone marrow at twice the rate of red blood cells. However, in a given sample of blood, nearly 45% of the blood consists of red blood cells and less than 1% is made of white blood cells.
- a. Suggest a reason for the lower volume of white blood cells in a sample of blood even though they are produced at twice the rate of red blood cells.
 - b. Most agents that cause disease are outside the bloodstream and are found in the fluid spaces between tissue cells. Use this information to develop another reason for the lower volume of white blood cells in a sample of blood.

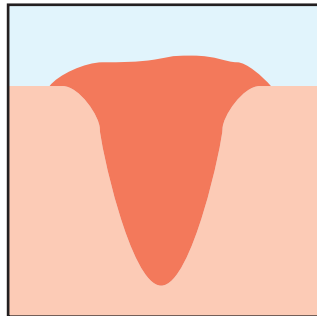
Platelets

Think back to the last time you had a small scrape or a minor cut to your skin and the tissues below your skin. The bleeding usually stops after a few minutes because **proteins** in your blood work to form a plug that seals the damaged blood vessels. A protein present in blood and capable of forming a plug is called **fibrinogen**. This protein remains inactive until called into action by the platelets.

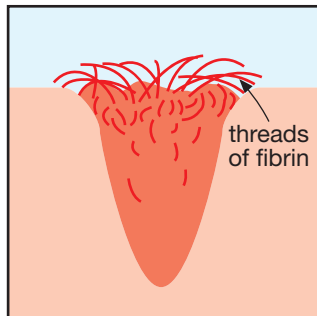
Platelets rupture when they come into contact with a rough surface, and they trigger a complex series of chemical reactions. These reactions cause the dissolved fibrinogen protein to convert to its active form—a thread-like protein called **fibrin**. The fibrin threads become interwoven to produce a mesh that traps red blood cells. As more red blood cells get caught in the net of fibrin, the combination of these fibres and blood cells produce a thick red jellylike substance called a **blood clot**. When this mesh of threads and red blood cells hardens and dries, it is called a scab. The skin under the scab heals and the scab eventually falls off.

The Clotting Process

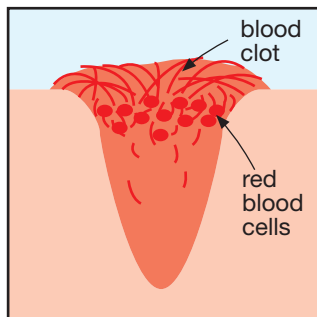
The skin is cut. Blood starts leaking out of the body to wash out dirt and germs from the cut.



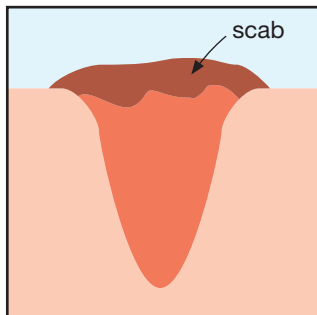
Platelets come into contact with the rough surface of the cut. The platelets rupture and release chemicals that convert fibrinogen into threads of fibrin.



Red blood cells get caught in the fibrin net to form a blood clot.



The clot hardens to form a protective barrier known as a scab.



Many life-threatening medical conditions are related to blood clotting. A diet high in fat can make the walls of arteries become rough—this causes platelets to adhere and produce blood clots inside the vessel. A blood clot in these circumstances can lead to serious cardiovascular problems, including heart attacks or strokes.

Some people lack the ability to produce the necessary blood proteins that allow platelets to form a clot. For these individuals, even minor cuts and bruises bleed excessively and take much longer to heal. This condition is called **hemophilia**. To keep healthy, people with hemophilia often need transfusions of protein clotting factors and platelets.

- ▶ **fibrin:** a thread-like insoluble protein formed from fibrinogen
The threads of fibrin mesh to form the fabric of a blood clot.
- ▶ **blood clot:** a jellylike, solid mass consisting mainly of red blood cells trapped in a net of fibrin fibres
- ▶ **hemophilia:** a blood disorder involving the blood's reduced ability to clot, which can lead to excessive bleeding



DID YOU KNOW?

Alexei Romanov, the son of Nicholas II—the last Tsar of Russia—had hemophilia. At the time, there was little understanding and no treatment for the disease. Alexei's mother, Alexandra, employed the help of a self-proclaimed healer named Rasputin to help Alexei. Some people believed that Rasputin was able to use hypnosis to help control Alexei's condition and slow his bleeding. Rasputin was hated by many Russians for his powerful influence with the royal family, and he was killed by his enemies in 1916.



Investigation

Observing a Prepared Blood Smear



Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

Purpose

You will use prepared slides of human blood to observe the structure and abundance of the cellular components of blood.

Materials

- prepared human blood slides
- compound microscope
- blank unlined paper
- pencil

Procedure



- step 1:** Review basic microscope skills by reading the handout “Using a Microscope” from the Science 30 Textbook CD.
- step 2:** Obtain a prepared human blood slide and view the slide under high-power magnification.
- step 3:** Identify and draw to scale a red blood cell, two white blood cells, and platelets—perhaps these are only barely visible. Remember that the blood sample is most likely stained for better visibility and, therefore, the colours may not be representative. Label the three cellular components of blood on your drawing. Include a label for the white blood cell nucleus.
- step 4:** Count and record the number of red blood cells and white blood cells in the field of view.

Analysis

1. Describe two physical differences between the observed red blood cells and white blood cells.
2. The function of red blood cells is to transport oxygen. How is a red blood cell's shape and structure related to its function?
3. Compare the two white blood cells that you sketched in step 3. Describe how these two cells are similar. Describe how they are different.
4. State the ratio of red blood cells to white blood cells in the section of the prepared blood slide that you observed.

Plasma



Plasma is a yellowish liquid that is like soup broth, because it is mostly water with substances dissolved or suspended in it. More than half of blood is composed of watery plasma. The plasma holds and transports such substances as the following:

- cells of the blood—red blood cells, white blood cells, and platelets
- dissolved waste carbon dioxide from the capillaries to be excreted out at the lungs
- urea, a waste product from the liver filtered by the kidneys to become urine
- hormones from glands
- digested nutrients such as glucose, amino acids, vitamins, and minerals from the digestive tract
- proteins such as fibrinogen that aid in blood clotting, as well as other proteins like antibodies involved in the immune response

When patients have lost a lot of blood due to an accident or major surgery, they may be given donated plasma to replace the lost fluid.

Practice

Use the following information to answer questions 27 to 30.

The majority of blood collected at a blood donation clinic is not left as whole blood. It is instead separated by a centrifuge into its components of red blood cells, plasma, and platelets. In this way, your single donation of one blood unit can help three other people.

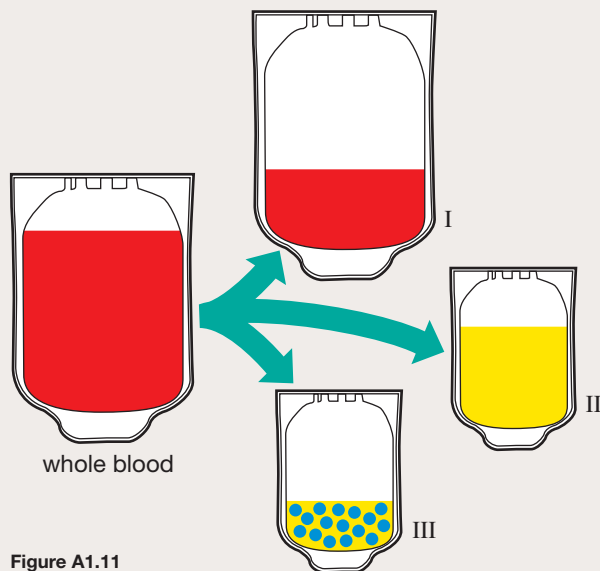


Figure A1.11

27. Refer to Figure A1.11. Identify the blood component that corresponds best to each of bags I, II, and III.
28. Burn victims suffer a significant loss of skin tissue and are, therefore, highly susceptible to deadly dehydration. What blood component best addresses this problem?
29. A cancer patient receiving radiation treatment is often unable to produce enough of a key blood component that prevents uncontrollable internal bleeding. Identify the blood component given to this patient in a transfusion.
30. Explain the following statement:
 "Every time you give blood you can save up to three lives."

1.3 Summary

The typical human body contains about 5 L of blood that transports materials around the body to help prevent disease. Blood is a mixture of living and non-living components: red blood cells, white blood cells, platelets, and plasma.

The disc-shaped red blood cells are full of a molecule called hemoglobin, which allows these blood cells to carry and transport oxygen to the body's cells. White blood cells are designed to help protect the body from disease-causing organisms. Platelets are the blood parts that make blood self-sealing. When there is a cut, platelets form a clot to stop the loss of blood—people with hemophilia lack key factors in their blood that help form clots. Plasma is a yellowish liquid that the blood cells and platelets float in. Many substances are dissolved in plasma, including glucose, urea, and hormones.

1.3 Questions

Knowledge

1.
 - a. List the four components of blood in decreasing order of their relative volume in whole blood (from most abundant to least abundant).
 - b. Sketch a scale diagram of each component of question 1.a.
2. Obtain a copy of the handout "Blood Smears" from the Science 30 Textbook CD. The first five blood smears on this handout come from a healthy patient. The sixth blood smear is from a patient with neutrophilia.
 - a. Identify the major difference between the blood smears from the healthy patient shown in slides 3, 4, and 5 with the blood smear from the patient with neutrophilia on slide 6.
 - b. Suggest a possible reason for the difference you identified in 2.a.



Applying Concepts

3. Carbon monoxide is a colourless, odourless gas produced during the combustion of fossil fuels, including gasoline. Carbon monoxide binds to the hemoglobin in red blood cells much faster and more strongly than does oxygen. Based on your knowledge of the role of red blood cells, explain why exposure to carbon monoxide can be so dangerous.
4. Leeches and vampire bats are both parasites that feed on animal blood. After they use their sharp teeth to cut the surface of the animal's skin, they release a blood-thinning chemical called an anticoagulant that not only stops blood from clotting but also allows greater blood flow by dilating blood vessels.

Explain why an anticoagulant might be useful for treating circulatory system problems.

5. Leukemia is a type of cancer where the body produces large numbers of abnormal blood cells—particularly white blood cells—that do not function properly.
 - a. How could having improperly functioning white blood cells affect people with leukemia?
 - b. Why would doctors treat leukemia by giving patients a bone marrow transplant?
6. Do you meet the basic criteria to be a blood donor? Use the Internet to gather information about the basic eligibility criteria for donating blood in Canada.

